Version SKH/2

EGT2
ENGINEERING TRIPOS PART IIA

Wednesday 23 April 2014 9.30 to 11

Module 3D1

GEOTECHNICAL ENGINEERING I

Answer not more than ***three*** *questions.*

All questions carry the same number of marks.

The ***approximate*** *percentage of marks allocated to each part of a question is indicated in the right margin.*

Write your candidate number ***not*** *your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper
Graph paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Attachment: 3D1 & 3D2 Geotechnical Engineering Data Book (19 pages).
Engineering Data Book

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

1 A 5 m high flood embankment is to be constructed on a 10 m thick layer of clay underlain by permeable sandstone. A Proctor standard compaction test carried out on the material selected for embankment construction gives the data shown in Table 1.

Water content (%)	11	14	17	20	23
Bulk density (kg m^{-3})	1835	1938	1989	1980	1950

Table 1

(a) (i) Calculate the optimum water content for standard compaction of the embankment material. [20%]

(ii) The embankment material is readily available on-site at a range of water contents. Comment on the likely behaviour of the material following compaction at water contents above and below the optimum water content. What guidance might be given to the contractor in order to select an appropriate material? [20%]

(b) (i) Following construction of the embankment, the settlement of the clay surface beneath the embankment is monitored giving the data shown in Table 2. Assuming one-dimensional consolidation in the clay, estimate the ultimate settlement of the clay surface and the coefficient of consolidation of the clay. [25%]

(ii) How long after embankment construction will the rate of settlement reduce to below 1 mm per month? [35%]

Time after construction	6 months	1 year	2 years	5 years	10 years
Settlement	27 mm	38 mm	54 mm	85 mm	112 mm

Table 2

2 The ground conditions at a construction site consist of a 4 m thick silt layer overlying 10 m of clay, beneath which is a permeable sandstone bedrock. The silt layer has a unit weight of 18 kN m^{-3} and the clay a unit weight of 16 kN m^{-3}. The water table lies at 4 m depth. Oedometer test data for the clay and silt are given in Table 3. The permeability of the clay is 10^{-9} m s^{-1}.

Applied Stress (kN m^{-2})	20	60	100	140	180	220
Silt height (mm)	20.00	19.89	19.84	19.81	19.78	19.76
Clay height (mm)	20.00	19.60	19.41	18.80	18.35	17.98

Table 3

(a) Construction of an embankment on the surface of the clay layer results in a surcharge of 50 kN m^{-2} being applied to the surface of the silt.

(i) What ultimate settlement will be experienced once consolidation is complete? [20%]

(ii) How long will it take for 90% of consolidation settlements to occur? [20%]

(b) In order to accelerate settlements, an additional surcharge of 50 kN m^{-2} is applied to the embankment crest which is removed once settlements reach the value calculated in part (a). For how long must this surcharge be in place and how much further settlement might be expected to occur after the surcharge is removed? [50%]

(c) Describe another method that might be used to accelerate the consolidation period. [10%]

(TURN OVER

3 A temporary open cutting is planned in clayey soil. The depth and slope of the cutting are H and 60°, as shown in Fig. 1. The undrained strength of the clay is 50 kN m^{-2} and its total unit weight is 18 kN m^{-3}. A surcharge of 30 kN m^{-2} is applied at the top surface. A failure mechanism involving a triangular wedge OAB, as shown in Fig. 1, is assumed. The angle of the failure line to the horizontal level is θ and the velocity of the wedge parallel to the failure line is v.

(a) Find the length of the line AB and the area of the triangular wedge OAB as functions of θ and H. [15%]

(b) Compute the rate of potential energy loss of the wedge and the surcharge. [20%]

(c) Find the length of the failure line OB as a function of θ and H. Compute the dissipative work rate. [20%]

(d) Using the rates computed above, show that the optimal θ is 30° and find the maximum cutting depth. [35%]

(e) Discuss whether this mechanism is the best solution for the problem. [10%]

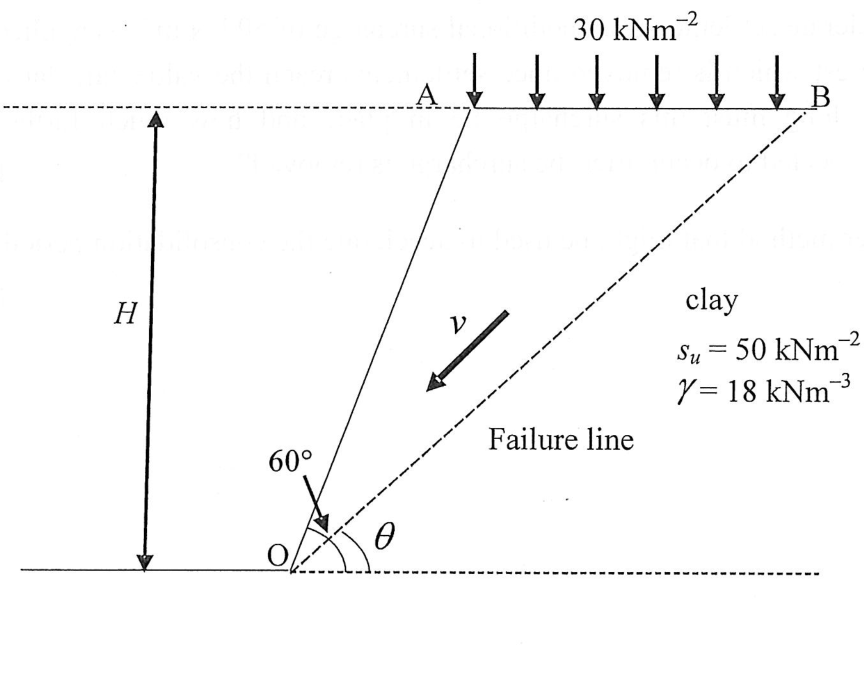

Fig. 1

4 A strip foundation of 5 m width and 1.5 m thickness is placed in dry sandy soil as shown in Fig. 2. A vertical load P is applied to the top of the foundation. A surcharge σ_s is applied at the ground surface next to the foundation. The critical state friction angle of the sand is 30°. The void ratio and dry unit weight of the sand are 0.63 and 16 kN m^{-3}, respectively. The unit weight of the concrete is 24 kN m^{-3}.

(a) The foundation is expected to fail when the vertical load is 9 MN m^{-1}. Evaluate the maximum and minimum principal stresses at point A, which is located beneath the foundation. [15%]

(b) Evaluate the maximum and minimum principal stresses at point B, which is at the foundation level. Define them as a function of σ_s. [15%]

(c) Using the stress fan concept, evaluate the contribution of the surcharge to the bearing capacity of the foundation. Considering the self-weight effect using the bearing capacity formula adopted by Eurocode 7 (see the Geotechnical Engineering Data Book), find the minimum surcharge load σ_s that needs to be added at the ground surface to ensure that the foundation is safe. [30%]

(d) If the groundwater table is at the foundation level, estimate the minimum surcharge load. Assume that the void ratio does not change when the soil is submerged. [20%]

(e) If the groundwater table rises to the ground surface, estimate the minimum surcharge load. [20%]

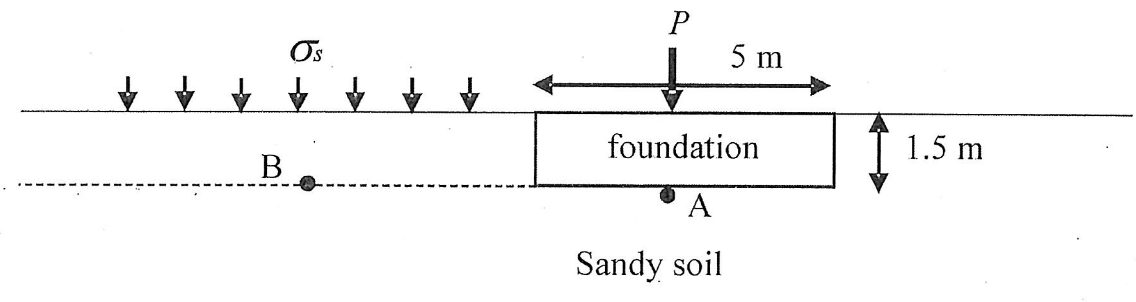

Fig. 2

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3D1 2014 Numerical Answers

1. a) i) 15.5%
   b) i) 114 mm, 3 m^2/yr
      ii) 2.94 yrs

2. a) i) 394 mm
      ii) 4.76 yrs
   b) 1.55 yrs, 12.6 mm

3. d) 15.9 m
4. c) 30.1 kPa
   d) 47.1 kPa
   e) 55.7 kPa